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METHOD AND COST OF RECOVERING QUICKSILVER FROM LOW-GRADE ORE AT THE REDUCTION PLANT OF THE SULPHUR BANK SYNDICATE, CLEARLAKE, CALIF.

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METHOD AND COST OF RECOVERING QUICKSILVER FROM LOW-GRADE ORE AT THE REDUCTION PLANT OF THE SULPHUR BANK SYNDICATE, CLEARLAKE, CALIF.[1]

By Worthen Bradley[2]

INTRODUCTION

This paper describing the metallurgical practice and costs at the reduction plant of the Sulphur Bank Syndicate, Clearlake, Calif., is one of a series of papers on the treatment of ores being prepared by the Bureau of Mines.

The reduction plant and mine of the Sulphur Bank Syndicate are on the eastern shore of Clear Lake, in Lake County, Calif., 4 miles from the town of Clearlake and 125 miles north of San Francisco.

About 30 men are employed at the mine and reduction plant. The average daily production of quicksilver for the year 1929 was 4.19 flasks, each flask containing 76 pounds, 1 ounce. The quicksilver is delivered by automobile truck, railroad, and boat to San Francisco for marketing.

The ore occurs as a surface deposit, covering about 100 acres to an average depth of 5 feet. Mining is done by the open-cut method with two 1 cubic yard shovels each operated by a 75-hp. Diesel engine. The ore is loaded by the shovels into automobile trucks, each truck having a capacity of 8 cubic yards. The trucks haul the ore about one-fourth of a mile to a bin at the lower terminal of an inclined tramway to the plant. The ore is dumped directly into the bin through an inclined grizzly with 9-inch openings; the grizzly is made of 70-pound rails. The oversize boulders slide over the grizzly onto a waste pile which is removed from time to time by the power shovels and trucks. From this bin the ore is loaded into 2-ton capacity skips and hoisted to the bin at the upper end of the plant.

The plant site is on the side of a hill about 1,000 feet from the shore of Clear Lake and 150 feet above it. The lake is 1,350 feet above sea level.

The capacity of the screening and sorting plant is 300 tons per day; the capacity of the furnace plant is 43 tons per day.

Water for the reduction plant is pumped from the lake to a height of 300 feet by a two-stage centrifugal pump direct connected to a 50-hp., 1,800-r.p.m. motor. The pipe line is 6 inches in diameter and discharges into two steel storage tanks each 26 feet in

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2 - One of the consulting engineers, U. S. Bureau of Mines, and manager, Sulphur Bank Syndicate.

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diameter and 16 feet high and having a combined capacity of 127,000 gallons. About 75,000 gallons of water per day are required for use in the reduction plant.

Power is purchased from the Pacific Gas and Electric Co. It is transmitted to the plant at 11,000 volts and stepped down to 440 volts for all mine and plant motors.

ACKNOWLEDGMENTS

The author acknowledges the assistance of William O. Vanderburg, associate mining engineer, U. S. Bureau of Mines, and of W. H. Enderton, A. F. Wolbert, P. W. Cox, Jas. Storey, and C. W. Hart, of the Sulphur Bank staff, in the preparation of this paper.

ORE TREATED

The ore deposit consists of grains of cinnabar finely disseminated throughout a gangue composed principally of altered basalt with subordinate amounts of elemental sulphur and opal. The altered basalt is soft and porous and averages about 30 per cent moisture. Large bowlders of partly altered basalt which are barren of value occur in the deposit. The distribution of the cinnabar through the basalt is not uniform. Samples taken over the entire area covered by the ore deposit range from a trace to 10 pounds of quicksilver per ton, the average being about 0.1 per cent or 2 pounds per ton. Only that material which, after passing through a screen with 1-inch holes, will assay 6 pounds of mercury per ton or better is considered furnace ore. The cinnabar occurs mostly in the fines, as is shown by the following screen analysis of low-grade ore:

Screen analysis of low-grade ore

Screen size	Weight, per cent	Assay, pounds mercury per ton
On 2-inch, square mesh	30.5	1.75
Through 2-inch on 3/4-inch, square mesh	44.5	2.20
Through 3/4-inch on 1/4-inch, square mesh	11.8	4.25
Through 1/4-inch, square mesh	13.2	11.50
Composite	100.0	3.53

The free sulphur content in the ore varies from 1 to 15 per cent with an average of about 2 per cent. The ore is highly acid, and the action of the acid on the gangue results in a large amount of slime.

BRIEF HISTORY OF FURNACE OPERATIONS

The Sulphur Bank ore deposit was originally worked for sulphur as far back as the sixties, but difficulty was encountered in refining the product due to the presence of cinnabar. The deposit was first mined for the recovery of quicksilver from 1873 to 1883. Subsequent periods of operation were 1887 to 1897; 1899 to 1905; 1917 to 1918; and 1927 to the present time. Up to 1927, when the Sulphur Bank Syndicate acquired control of the property, the mine was credited with a quicksilver production of 92,400 flasks. In spite of the large production, considerable difficulty was experienced in furnace practice. The high free-sulphur content of the ore proved a barrier to complete separation of the quicksilver, as

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part of the sulphur and mercury would recombine in the condensers, forming synthetic cinnabar which had to be retorted. Attempts at concentration by tables met with difficulty when it came to retorting the concentrates, because the elemental sulphur present formed an iron sulphide with the iron of the retorts.

PRESENT METHOD OF RECOVERY

The present method of recovery consists of the following operations:

1. Screening and sorting the low-grade ore to obtain a furnace feed containing 8 to 10 pounds of quicksilver per ton.
2. Treatment of the ore in a rotary kiln.
3. Precipitating most of the dust carried from the furnace in the gas stream.
4. Condensing mercury from the gas stream as (a) high-grade mud and (b) low-grade mud concentrates.
5. Flotation treatment of low-grade condenser mud to obtain high-grade concentrates.
6. Drying and retorting of high-grade condenser mud and high-grade flotation concentrates, making a finished product.

Screening and Sorting

Figure 1 gives the flow sheet of the screening and sorting plant and Table 1 gives details of equipment.

Of the 300 tons of run-of-mine ore fed per day, to the screening and sorting plant about 60 per cent is rejected as waste; of the remaining 40 per cent, or 120 tons, 43 tons per day is treated in the kiln and the balance of 77 tons per day stored in a stockpile. When the stockpile reserve has been built up to about 5,000 tons, the screening and sorting plant is closed down and the ore for the furnace is drawn from the stockpile until the accumulated supply is almost exhausted.

From the plant bin which has a capacity of 40 tons, the low-grade ore is fed to a trommel by an Allis-Chalmers apron feeder 3 feet wide on 7-foot centers, chain-driven by a 4-1/2-hp. motor, connected to a variable-speed, Link-Belt reduction unit. A swinging gate is installed above the discharge end of the feeder to prevent the large bowlders from hitting the trommel with too much of an impact. The trommel is 8 feet long and 42 inches in diameter and is made of 3/4-inch iron plate with 1-inch diameter punched holes. It is placed on a slope of 5° and is belt-driven by a 15-hp. motor.

The oversize product of the trommel passes onto an inclined 6-ply, rubber-surfaced picking belt, 36-inches wide, with 1/4-inch top cover and 1/32-inch bottom cover. The belt is 40 feet long, center to center, and is driven at a speed of 40 feet per minute by a 5-hp. motor. A series of water sprays wash the remaining fines from the coarse material and a sorter picks out the pieces of ore. About 20 tons of ore per month is sorted by hand from the picking belt. The reject from the picking belt goes to a stacking belt which carries

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it to the waste dump.

The sorted ore from the picking belt is dropped into a 25-ton bin, and when this bin is full the ore is run through a 20 by 10 inch Blake-type crusher and crushed to minus 2 inches. The crushed product is conveyed by a travelling belt to the conveyer belt carrying the minus 1-inch undersize product of the trommel to the stockpile or furnace.

The fines washed from the picking belt are conveyed by launder to a Deister-Overstrom concentrating table. A shaking screen with 1/4-inch square holes removes wood from the fines before concentrating. The table produces concentrates containing about 1,000 pounds of quicksilver per ton. About 90 pounds of quicksilver is recovered by the table per month, the table operating daily, while the screening and sorting plant is in operation. The tailings from the table, which contain about 6 pounds of quicksilver per ton, are conveyed by launder to one of two storage ponds. When one storage pond is full, the table tailings are turned into another and the first pond is allowed to dry out. The tailings are eventually shoveled out of the pond into trucks and hauled to the stockpile.

The cinnabar concentrates, after drying, are retorted to recover the quicksilver. Retorting gives a higher recovery of quicksilver than furnace treatment, and it is for this reason that the fines washed from the picking belt are concentrated to recover part of the values for retort treatment before the material is sent to the storage ponds and thence to furnace treatment.

Furnace Treatment and Condensing Plant

Figure 2 gives a flow sheet of furnace treatment, dust precipitation, and condensing plant treatment. Table 1 gives the details of equipment used.

Furnace Treatment

When the screening and sorting plant is in operation the ore is conveyed by a travelling belt to the stockpile and thence by dragline, conveyor, and elevator to the furnace ore bin, which is of wood-stave construction and has a capacity of 50 tons.

From the furnace bin the ore is fed uniformly, at the rate of about 1.8 dry tons per hour, onto a traveling belt by a 30-inch Challenge feeder, and is discharged by the belt into the kiln. An electrical device, shown in Figure 3A, stops the belt and feeder if the ore is not being fed uniformly to the kiln. This device consists of two electrically connected contact straps which are suspended in the ore stream discharged by the feeder. The ore stream keeps the straps separated so that the electric circuit is open. If the ore stream is interrupted the straps come together, closing the electric circuit and starting a motor connected to a speedometer; at the same time an electric horn is sounded, which notifies the attendant, who may be elsewhere employed, that something is wrong with the ore feed. The speedometer, which is driven by a 1/32-hp. motor, registers the motor speed in miles per minute. The number of miles shown by the speedometer multiplied by the factor 0.54 gives the time in minutes that the belt was not running.

The speedometer and horn are also operated by closing the clutch switch or opening either the conveyor magnetic switch or contacts in the kiln feed hopper, as shown in Figure 3B. When the magnetic switch is opened, an extra arm clamped to its switch point axle makes contact with another point in the 110-volt speedometer and horn circuit.

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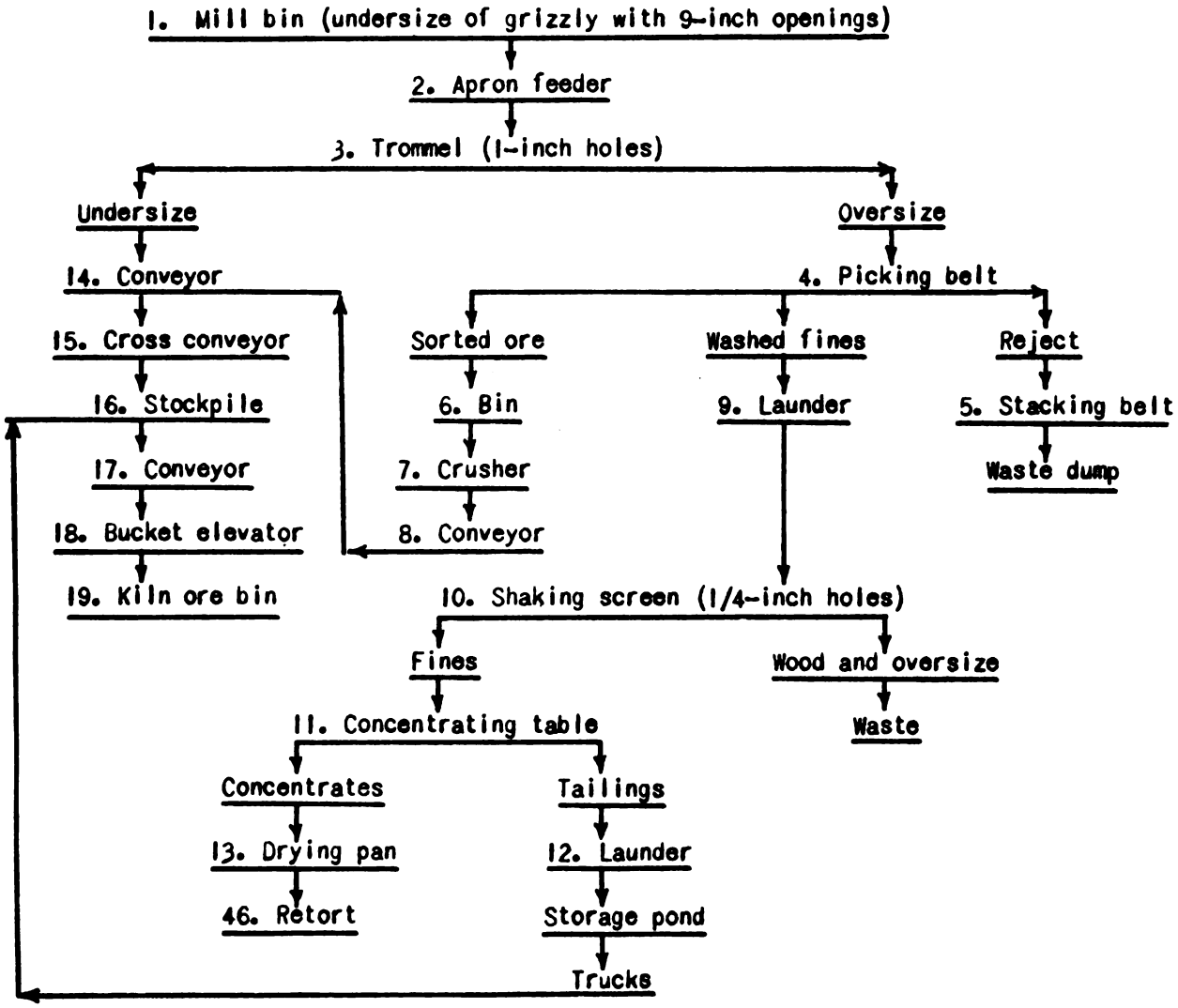

Figure 1.- Screening and sorting plant flow sheet. The numbers refer to details of equipment given in Table 1

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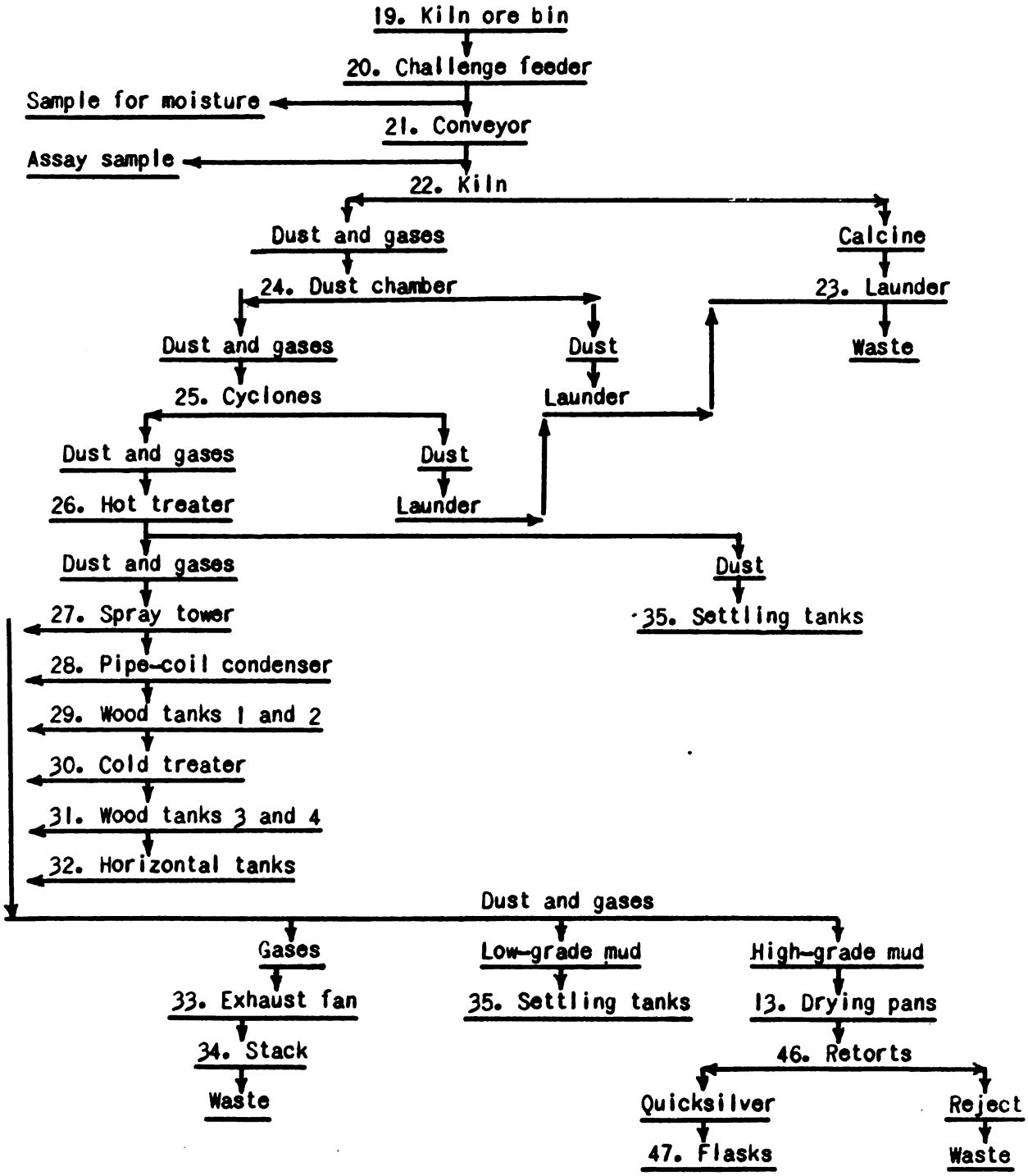

Figure 2.- Reduction and condensing plant flow sheet. Numbers refer to details of equipment given in Table I

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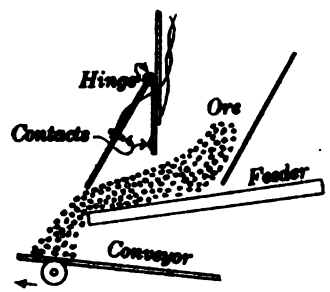
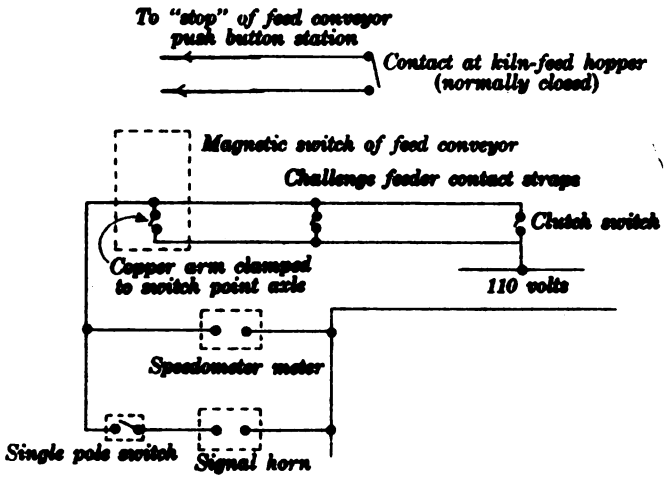
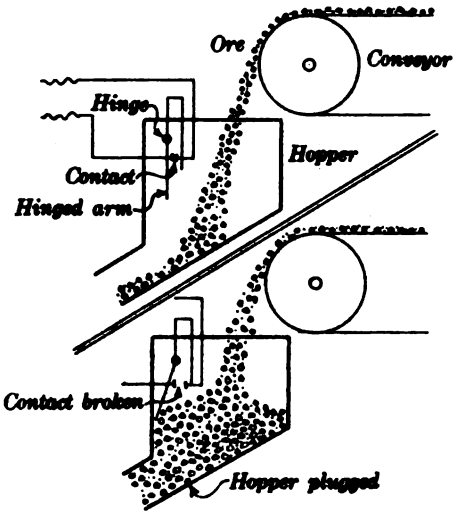


A.–SKETCH OF CONTACT STRAPS AT CHALLANGE FEEDER (SIDE ELEVATION)


To "stop" of feed conveyor push button station
Contact at kiln-feed hopper (normally closed)
Magnetic switch of feed conveyor
Challenge feeder contact straps
Clutch switch
Copper arm clamped to switch point axle
110 volts
Speedometer meter
Single pole switch
Signal horn

B.–WIRING DIAGRAM



C.–SKETCH OF CONTACT AT KILN-FEED HOPPER

Figure 2.–Automatic kiln-feed shut-off system

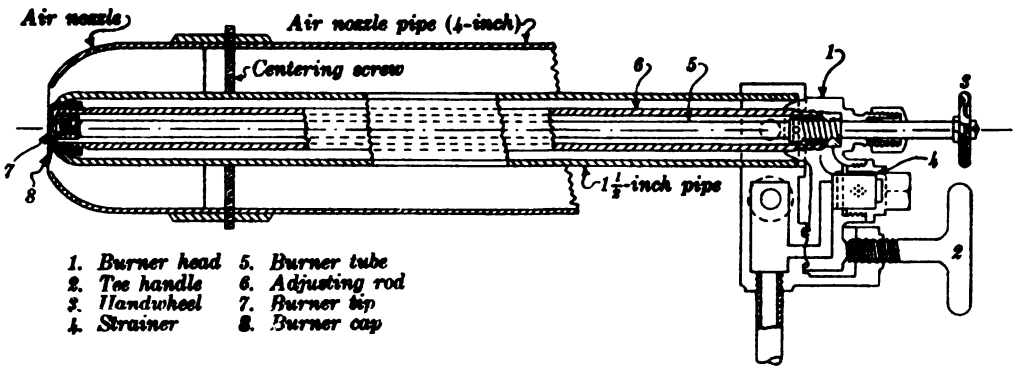


Figure 4.–Ryder burner

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The contacts in the kiln feed hopper are opened when the throat of the hopper is plugged, the ore building up against a movable hinged arm (see fig. 3C). Opening these contacts opens the magnetic switch, via the "stop" side of the push button station. A switch was cut into the horn circuit so that its operation could be avoided during shut-downs.

A sample of the ore is taken automatically at 5-minute intervals, as the ore drops from the conveyor belt into the furnace. The samples thus taken are combined into a composite sample for each shift.

In feeding the ore into the furnace, back-spilling is prevented by a set of six helical blades, 2 feet long, arranged around the inside of the kiln at the feed end. These blades help in carrying the ore away from the head of the kiln.

The rotary kiln, as first built and installed by the Pacific Car and Equipment Co., was 40 feet long and had an outside diameter of 5 feet and an inside diameter of 3 feet 10 inches. A 20-foot section was added later, making the kiln 60 feet in length. It was thought that by adding 20 feet to the length of the kiln the daily tonnage treated would be increased. Although the additional length failed to increase the capacity it proved more efficient in burning the sulphur out of the ore. The kiln has a slope of 1/2-inch per foot and is gear driven by a 7-1/2-hp., 900-r.p.m. motor.

The kiln lining consists of 2-1/2 inches of Diatex brick next to the shell and 4-1/2 inches of monolithic lining made of crushed fire brick and Lumnite cement in the proportion of 3 to 1, respectively. The materials required for lining the kiln are as follows:

Diatex bricks, size 2-1/2 by 4-1/2 by 9-inches, number of bricks	4,500
Black building paper, square feet	1,000
Lumber, size 1 by 6 inch by 10 foot, number of pieces	100
Tacks, pounds	8
Raw fire clay, cubic feet	20
Portland cement, sacks	25
Powdered infusorial earth, cubic feet	20
Lumnite cement, barrels	35
Crushed fire brick, cubic yards	15

The Diatex brick are chamferred on one side to fit the kiln shell. The mix of the mortar for the Diatex brick consists of 30 per cent by weight of raw fire clay, 40 per cent Portland cement, and 30 per cent of powdered infusorial earth. The mix for the fire brick concrete is 1 part by volume of Lumnite cement and 3 parts by volume of fire brick, crushed to minus 1-inch size with the coarse and fines taken together. The mix is used dry as possible and the concrete is well tamped behind movable wood forms. Building paper is used between the brick and the monolithic lining to prevent the brick from absorbing the moisture from the concrete. The forms are removed at the end of the first eight hours, and the concrete is sprinkled for four hours after that, so that it will not lose its moisture too rapidly.

The time required for lining the kiln is as follows:

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	Hours
Allowing kiln to cool	24
Lining kiln	48
Setting	36
Burning wood in kiln to bring temperature up to 200°C	8
Burning oil in kiln to bring temperature up to 625°C. (feeding small amount of ore)	8
Total time required to line kiln and bring into operation	124

The number of man-hours required for lining the kiln and bringing it into operation is 632.

The life of the lining is about two years.

As a means of securing complete oxidation of the free sulphur in the ore, the feeding of the ore and the firing of the kiln are done at the same end of the kiln as contrasted with the standard practice of countercurrent movement of ore and furnace gases, in which the kiln is fed and fired at opposite ends. By employing parallel firing and feeding at the proper temperature and with sufficient oxygen in the kiln, no unburned sulphur vapor is carried into the gas stream, consequently there is no tendency for the sulphur to recombine with the quicksilver in the condensing system. It was hoped that the sulphur content of the ore would average 10 per cent and thus render the fuel requirement low. In calorific value, 50 pounds of sulphur is equal to 1 gallon of oil. However, the average sulphur content of the ore has been about 2 per cent.

The fuel oil, which is filtered, is preheated to 95°C. by a U-shaped section of the pipe line extending about 8 feet into the furnace. The oil is atomized by a pressure of 75 pounds per square inch and is fed into the furnace through a Ryder burner, shown in Figure 4. The oil pressure pump and the fan for supplying the low-pressure air for shaping the flame are driven by a 3-hp. motor.

The temperature of the gases leaving the furnace averages about 625°C. The temperatures of the oil and of the furnace gases are recorded every hour by means of a recording pyrometer manufactured by the Wilson-Maeulen Co., Inc. A recording meter, made by the National Meter Co., registers the oil consumption. The furnace draft is recorded and averages about 0.18 inch of water.

Figure 5 shows a plan and Figure 6 a side elevation of the furnace plant, including the dust-collecting and flume-condensing equipment.

Dust Precipitation

The dust-precipitating equipment, as first installed, consisted of a large steel dust chamber containing checker brickwork lining at the end of the kiln, a set of 8-inch diameter cooling pipes placed horizontally in parallel, and a Cottrell precipitator or so-called "hot treater." This equipment was necessarily elaborate as it was known that the rotary kiln makes large quantities of dust and that the Sulphur Bank ore contained a large amount of fines. After the plant was put into operation the amount of dust exceeded the estimated amount, and for that reason this section of the plant has undergone a number of changes. The amount of dust caught by the Cottrell precipitator was less than 50 per cent

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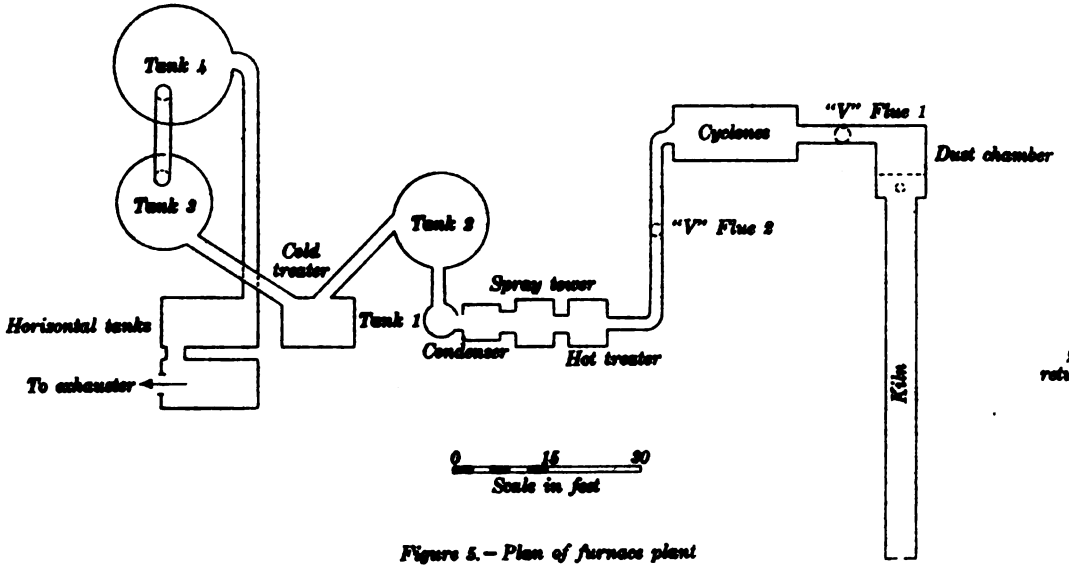

Figure 5.— Plan of furnace plant

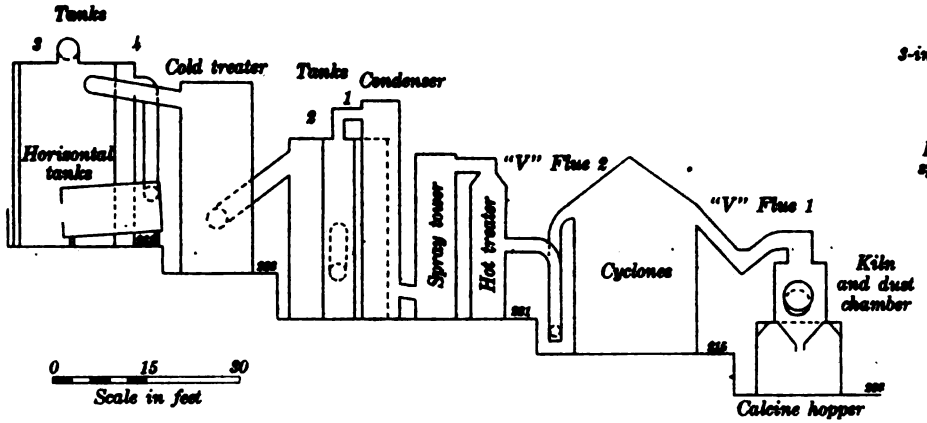

Figure 6.— East side elevation of furnace plant

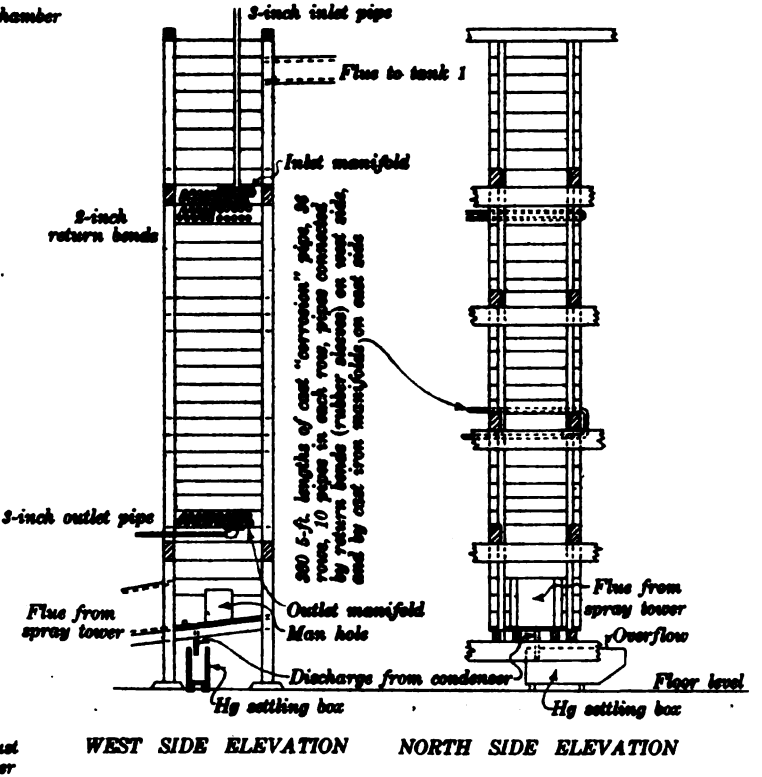
3-inch inlet pipe
Flue to tank 1
Inlet manifold
2-inch return bends
200 5-ft. lengths of cast "corrosion" pipe, 20 rows, 10 pipes in each row, pipes connected by return bends (rubber sleeves) on west side, and by cast iron manifolds on east side
3-inch outlet pipe
Flue from spray tower
Outlet manifold
Man hole
Discharge from condenser
Hg settling box
Flue from spray tower
Overflow
Floor level
Hg settling box
WEST SIDE ELEVATION
NORTH SIDE ELEVATION

Figure 7.— Pipe coil condenser

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of the total dust reaching it and the remainder caused a dust problem in the condensing system. The checker brickwork in the steel dust chamber and the horizontal cooling pipes choked up with dust so as to cause a loss of draft.

The dust-precipitating equipment, as it is now operating, consists of the steel dust chamber operating with a chain curtain instead of the former checker brickwork; 12 cyclone dust precipitators, in two sets of 6 each, the sets operating in parallel and replacing the cooling pipes formerly used; and the Cottrell precipitator. The 12 cyclones, each 24 inches in diameter, are so arranged that they can be placed partly in series. As the dust precipitating system is operated at present, a cooling of the gas stream takes place in the cyclones equal to that formerly afforded by the cooling pipes, the draft loss is reduced to a minimum, and most of the dust is precipitated. The amount of dust carried into the condensing system amounts to about 1 ton per day.

The temperature of the gases as they leave the cyclones averages about 235°C. The temperature is taken at the V-shaped flue connecting the cyclones with the Cottrell precipitator and is recorded every hour by an attendant.

Condensing

The condensing system as first installed in 1927, consisted of a brick spray tower, a wood condensing chamber with internal water coils, a Cottrell precipitator or so-called "cold treater," two circular wood-stave tanks placed horizontally, a steel exhaust fan enclosed in a wooden chamber, and a wood-stave stack 48 inches in diameter and 40 feet high. After this plant was in operation a short time, stack tests were made to determine the amount of quicksilver being lost in the gases expelled from the stack, and it was found that this loss amounted to 100 pounds of quicksilver per day. Additional units, consisting of four large circular tanks, were added to the condensing system as soon as possible. Subsequent stack tests made after the additional units were installed have shown the stack loss to be less than 10 pounds of quicksilver per day.

Each of the six wooden condensing tanks has a wooden partition which allows the gases to circulate through both halves of the tank. The bottom of each tank is inclined three-fourths inch per foot. By-pass arrangements are provided for each pair of tanks so that the monthly clean-up can be made without closing down the entire plant. During the warm weather the vertical wood tanks are kept wet on the outside. The water is piped to the drum head at the top of each tank, from where it overflows and runs down the sides.

The spray tower is equipped with a water-sealed outlet at the bottom through which the low-grade mud is drawn off continuously and carried by a launder to settling tanks for flotation treatment. The average flow of spray tower and condenser water is 20,000 gallons per day.

The water-coil condenser unit, shown in Figure 7, contains 360 Corrosiron pipes, each 5 feet in length and having an outside diameter of 2-1/2 inches.

A partial analysis of the Corrosiron pipe after one year's use was as follows:

Metallic mercury	Trace
Combined mercury	1.80 per cent
Sulphur	17.46 do.
Iron	23.60 do.
Insoluble	41.20 do.

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The average life of the Corrosiron pipe is about two years. An idea of the acidity of the gas stream can be gathered from the following test, recently made. A piece of common steel, suspended in one of the flues for five days, lost 0.116 per cent of its weight per day due to corrosion.

A steel fan was originally used for exhausting the gases, but its blades gave way and had to be replaced in nine months because of corrosion. The fan in present use is 100 inches in outside diameter and is made of Monel metal. It is direct-connected to a 25-hp. motor and operates at 500 r.p.m., exhausting the gases from the system at a water-gage pressure of 4-1/2 inches.

The volume of gases passing through the stack is about 6,500 cubic feet per minute. The mercury content in the gases is approximately 0.445 milligrams per cubic foot.

The draft at the inlet of the water coil condenser is 1.5 inches of water.

Flotation

The treatment of the low-grade mud from the condensing system, as first designed in 1927, was simple but proved to be inefficient. A series of launders, boxes, and riffles, together with a settling tank were used to catch the low-grade mud. The overflow from the settling tank was collected in a pond, and after settling and drying the mud was returned to the kiln with most of the mud caught in the launders, boxes, riffles, and settling tank. The mud collected was much greater in amount than anticipated and was of low mercury content. Treatment of the mud by drying and retorting was tried, but the amount greatly exceeded the capacity of the three D-retorts.

The problem of concentrating the mud to retort grade was satisfactorily solved by the installation of two additional settling tanks, a tank with agitating equipment and a two-cell Kraut flotation machine with auxiliary filtering apparatus.

In the present flotation flow sheet, shown in Figure 8, the low-grade mud from the condensing system flows by launder to either of two wooden settling tanks, each 16 feet in diameter and 5 feet high. The overflow from the tanks is conveyed by a launder to a third settling tank. The overflow from this third settling tank is sent to waste. A sample of the waste overflow is taken automatically every two minutes. Daily composite weights and assays of the solids in the overflow product show a quicksilver loss of less than 5 pounds per day.

The mud from the three settling tanks is collected into the sumps from where it is pumped by 2-inch Wilfley pumps to a tank equipped with a Devereux agitating machine, rotating at a speed of 25 r.p.m. From the agitator the pulp goes to the two-cell Kraut flotation machine in which the cells arranged in series. The pulp is circulated through the flotation cells about five times. When panning of the froth shows little mineral of value, the tailings are sent to waste.

The flotation heads average about 74 pounds of quicksilver per ton; the concentrates about 600 pounds per ton; and the final tailings about 2 pounds per ton. Pulp density is approximately 20 per cent of solids by weight.

The flotation reagents and amounts used per ton of original ore treated are as follows:

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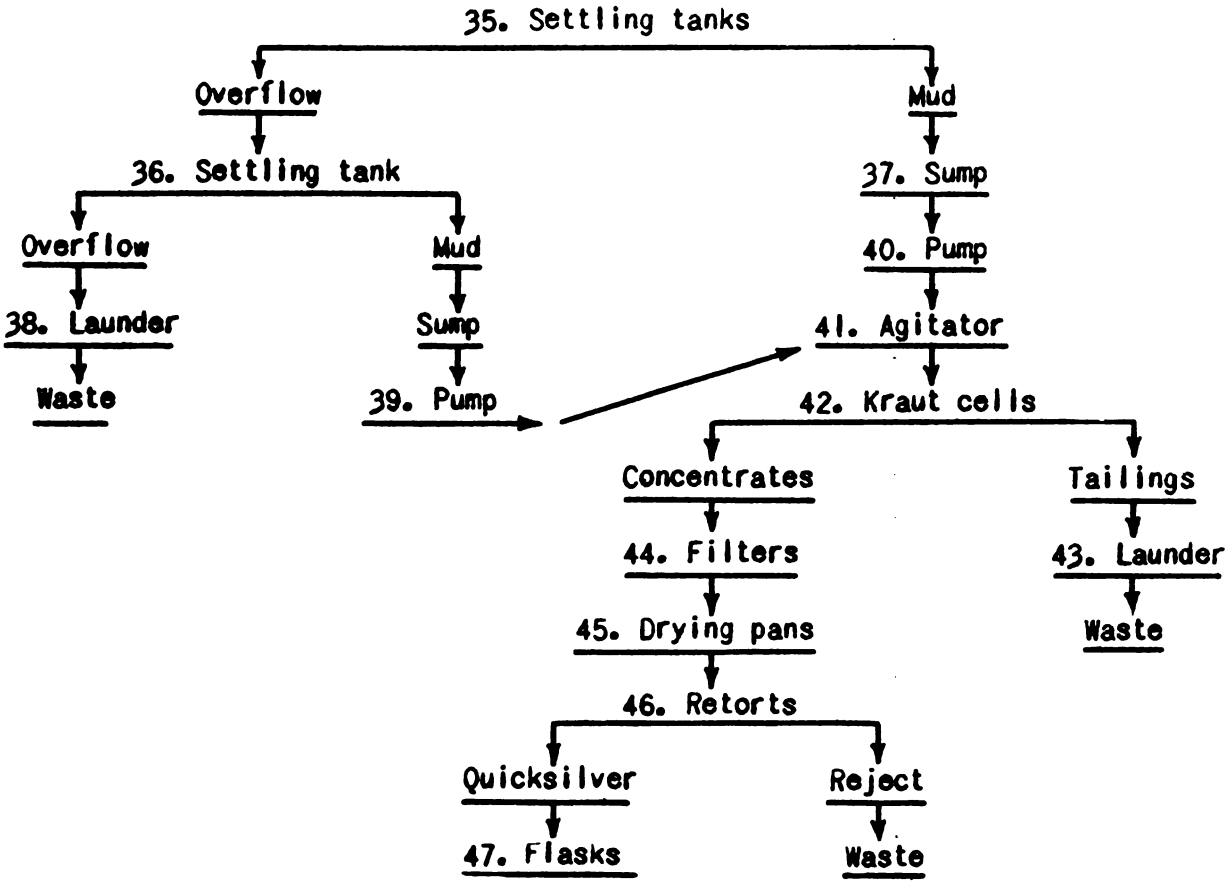

Figure 8.- Flotation flow sheet. Numbers refer to details of equipment given in Table I

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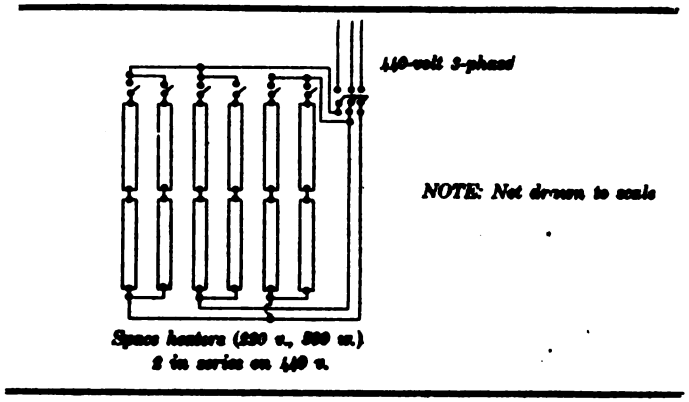
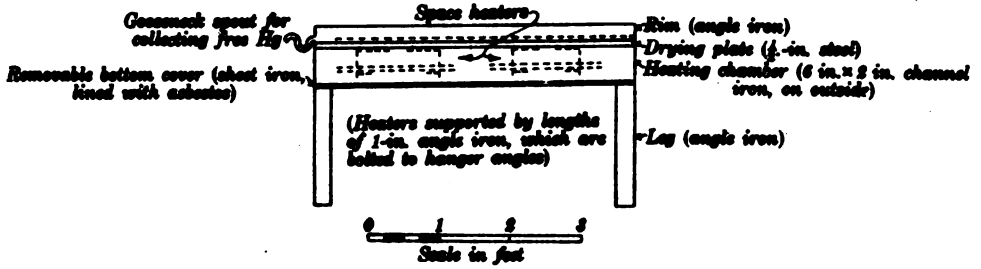
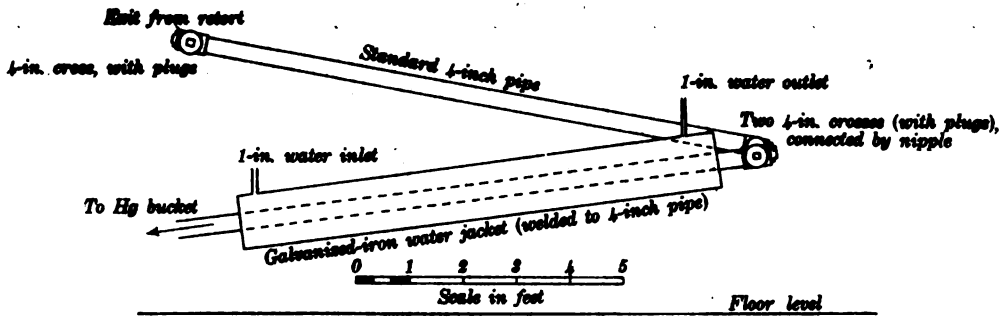


WIRING DIAGRAM


Gooseneck spout for collecting free Hg
Space heaters
Rim (angle iron)
Drying plate (¼-in. steel)
Heating chamber (6 in. × 2 in. channel iron, on outside)
Removable bottom cover (sheet iron, lined with asbestos)
(Heaters supported by lengths of 1-in. angle iron, which are bolted to hanger angles)
Leg (angle iron)
0 1 2 3
Scale in feet

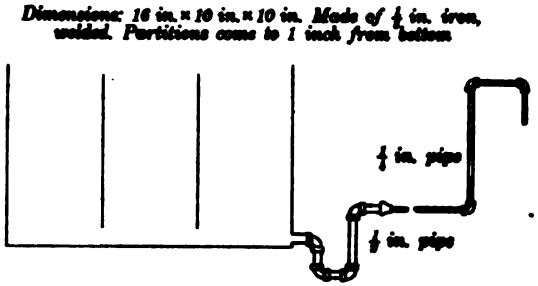
SIDE ELEVATION

Figure 9.—Electric drying pan

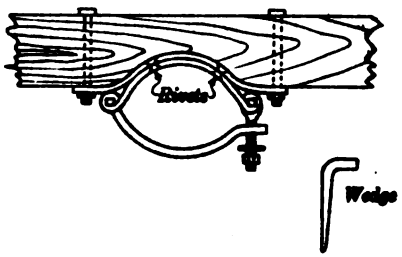

Exit from retort
4-in. cross, with plugs
Standard 4-inch pipe
1-in. water outlet
Two 4-in. crosses (with plugs), connected by nipple
1-in. water inlet
To Hg bucket
Galvanized-iron water jacket (welded to 4-inch pipe)
0 1 2 3 4 5
Scale in feet
Floor level

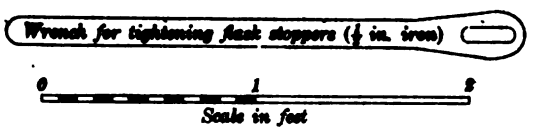
SIDE ELEVATION

Figure 10.—Retort condenser



A.—CELL FOR CLEANING QUICKSILVER
SIDE ELEVATION





B.—PLAN OF CLAMP FOR HOLDING FLASKS
WHEN TIGHTENING STOPPERS

Figure 11.—Cleaning cell and flask clamp

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	Pounds per ton
Sodium aerofloat	0.0543
Pine oil	0.3093
Barrett No. 4	0.0186

The flotation concentrates go to two drum filters made from 50-gallon oil drums and arranged in series. Filtering medium consists of 12-ounce duck placed over a screen with 1/4-inch holes. The screen in turn is placed over iron rods. The canvas filter cloths are changed every three days. The vacuum for dewatering the concentrates is supplied by an Oliver vacuum pump, belt driven by a 5-hp. motor. The vacuum is maintained at 25 inches of mercury.

Drying and Retorting

The dewatered flotation concentrates are dried in electrically heated drying pans (fig. 9). The concentrates are mixed with quicklime and sprinkled with water; the heat generated by the slacking of the lime aids the drying operation, and the lime added is also needed as a flux in the retorting of the dried concentrates product. The time required to dry a charge of about 325 pounds is eight hours.

After drying, the concentrates are retorted in three standard D-retorts. A working drawing of such a retort can be found on page 144 of Duschak and Schuette's "Metallurgy of Quicksilver," Bureau of Mines Bulletin 222. A retort charge weighs about 300 pounds and is left in the retort for a period of 24 hours. Retort residues mixed with water are used to seal the retort doors. Each retort is equipped with a Ray oil burner which has independent air and oil control. The condenser pipe leading from each retort is water-jacketed as shown in Figure 10. At the front of each retort, over the door, is a hood through which the retort gases can be drawn by means of a suction fan when the door is opened.

A cell for cleaning the quicksilver is shown in Figure 11A. The cell contains water, into which the quicksilver is poured. The quicksilver is cleaned by passing through the water, and is drawn from the cell through a 1/2-inch pipe nipple, welded close to the bottom of the cell. This nipple leads into a jointed pipe line with a series of bends; the pipe can be turned up or down to various levels, thus controlling the flow of the quicksilver. The pipe discharges into the weighing bucket which, when containing the correct amount of quicksilver is emptied into a flask. A device for holding the flasks while tightening the stoppers is shown in Figure 11B.

SAMPLING, ASSAYING, AND CONTROL OF OPERATIONS

In furnace treatment and subsequent operations the following products are sampled and assayed for mercury daily: Kiln feed, kiln calcine or residue, cyclone dust, low-grade mud, retort residue, flotation heads, concentrates, and tailings.

Mechanical samplers are used for the kiln feed, low-grade mud and flotation tailings. The stream of the first-named product is cut every five minutes by the sampler and the stream of the other two products every three minutes. The retort residue product is sampled by hand once each day and the remaining samples are taken by hand every hour.

In addition to the sample of kiln feed taken for assay purposes, two other kiln feed samples are taken, one of which is used for the computation of kiln feed tonnage and

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the other for the determination of moisture content. The sample for tonnage computation is taken at the Challenge feeder which discharges onto the kiln feed conveyor. The kiln-feed ore stream is cut and collected for 10 seconds once every hour. Each sample is weighed, and the weights are averaged for the day. Kiln-feed tonnage is computed from the average sample weight. At the time of taking the sample for tonnage computation, another grab sample is taken and put into a jar for determination of moisture content.

The amount of low-grade mud which is lost each day in the waste water is determined by timing the filling of a 5-gallon container once per hour and determining the solids in the water. The determination of solids is made by filtration of 3,065 cubic centimeters of the waste water taken from the sample obtained from the automatic sampler. The solids are weighed and the loss of low-grade mud is computed for the day.

The method of assaying in use at the Sulphur Bank plant was developed by the Bureau of Mines and is described in their Technical Paper 227.[3] Briefly, it is known as the "glass-tube method," and consists in separating the quicksilver by distillation in a closed tube, dissolving it in nitric acid, and titrating with potassium thiocyanate.

The sulphur is determined by the standard barium chloride method.

Once every four months a "stack test" is made to determine the daily amount of quicksilver expelled into the atmosphere. The apparatus used for this test can be set up at the stack proper, but for convenience is usually installed at the flue between condensing tank No. 4 and the horizontal tanks. This apparatus described in the order of flow consists of the following parts: A sampling tube inserted into the flue, a water-jacket condenser, a filter tube containing glass wool, a filter flask, a gas meter with draft gage and thermometer connected, and a jet. The mercury and water in the gas condense and drop into the condenser. The quicksilver is caught by the glass wool and the water goes into the flask. Calculations according to the following formula are made from the data secured by the above apparatus and readings from a thermometer and draft gage connected to the flue.

$$\text{Quicksilver lost per 24 hours, pounds} = \frac{\text{Milligrams of mercury in sample} \times \text{Total volume of gas leaving flue, cubic feet per minute} \times 3.17}{\text{Volume of gas metered for sample, cubic feet} \times 1{,}000}$$

The factor 3.17 is the product of the factors 0.0022, which changes grams to pounds, and 1,440, the number of minutes in 24 hours.

The assayer fills out a "daily sheet" which gives the wet weight of ore in tons, the per cent of moisture, the dry weight of ore in tons, fuel oil consumed in gallons per wet ton of ore and time lost in minutes. Figures for these items are given for each shift and are also totaled and averaged for the day. This sheet also gives weights and assays of kiln feed, low-grade mud, and flotation tailings; assays only of kiln residue, cyclone dust, flotation heads, and concentrates products; and the amount of quicksilver produced by pipe-coil condenser, retorts, and clean-ups. Retort production of mercury is itemized as follows: Condenser mud, flotation concentrates, and table concentrates.

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3 - Bouton, C.M., and Duschak, L.H., The Determination of Mercury: Tech. Paper 227, Bureau of Mines, 1920, 44 pp.

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For this daily sheet the assayer secures part of the information from the "daily kiln report," which is made out by the furnace-plant operators. A section of a typical daily kiln report would appear as follows:

Section of daily kiln report

Hour	Temperature, °C.						Drafts, inches of water			Color	
	Kiln	V flue No. 2	Condenser In	Condenser Out	Stack	Oil	Kiln	Condenser	Total	Mud	Kiln residue
7 a.m.	625	235	70	41	17	95	0.18	1.50	2.40	Gray	Gray

The operators fill in the above items hourly, and in addition give reasons for any shut-downs which might occur. The fuel-oil meter reading is put on this sheet once each shift.

It can be seen that the filling in of the daily kiln report requires the reading of a number of instruments, and the plant is well equipped in this respect. The kiln and oil temperatures are obtained from an indicating pyrometer, as previously described, with the Pyod thermocouples inserted in the dust chamber and in the intake of the oil preheating coil. The other temperatures are read from full immersion chemical thermometers. The kiln draft is indicated by a differential draft gage, with the tube inserted in V flue No. 1. The other drafts are read from standard U gages. The oil consumption is read from the previously described oil meter calibrated for 27° fuel oil.

The items "mud color" and "residue color" are filled in from visual observation, and are simply put down as a check on the instrument readings. When the color is gray, or any light color, conditions are satisfactory and little quicksilver is escaping.

Table 1.—Details of equipment

Note: The following numbers correspond to those given in the flow sheet diagrams of Figures 1, 2, and 8.

1. Inclined-bottom wooden bin, capacity 40 tons of wet ore, slope 45°.

2. Allis Chalmers apron feeder, 3 feet wide on 7-foot centers, chain-driven by 4-1/2-hp., variable-speed motor connected to link belt reduction unit.

3. Trommel, 8 feet long and 42 inches in diameter, slope 5°, made of 3/4-inch iron plate with 1-inch punched holes, belt-driven at speed of 18 r.p.m. by 15-hp. motor.

4. Picking belt inclined 15°, 36 inches wide, 6-ply, 32-ounce duck, rubber surfaced, 1/4-inch top cover, 1/32-inch bottom cover, on 40-foot centers, speed 40 feet per minute, belt-driven by 5-hp. motor.

5. Stacking belt inclined 20°, 30 inches wide, 6-ply, 32-ounce duck, rubber surfaced, 1/4-inch top cover, 1/32-inch bottom cover, on 150-foot centers, speed 150 feet per minute. Water spray on under side of belt at discharge end to wash off adhering fines. Belt-driven by 5-hp. motor.

6. Inclined-bottom wood bin with rack and pinion gate, 25 wet tons capacity; slope, 40°.

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Table 1.--Details of equipment (Continued)

7. Allis Chalmers 20 by 10 inch Blake-type crusher with manganese steel wearing plates. Belt-driven by 20-hp. motor.

8. Belt conveyor, 18 inches wide, 4-ply, 28-ounce duck, rubber surfaced, 1/8-inch top cover, 1/32-inch bottom cover, on 37-foot centers, speed 180 feet per minute. Belt-driven by a 3-hp. motor.

9. Box launder made of 1-inch boards, 4 by 6 inches in cross section, slope 7/8-inch per foot.

10. Shaker screen, 1/4-inch holes, belt-driven by 3-hp. motor.

11. Deister-Overstrom concentrating table, 6-1/2 by 14-1/2 feet, belt-driven by 5-hp. motor.

12. Wood launder made of 1-inch boards, V shaped, 12 by 12 inches in cross section

13. Electric drying pans, 4.5 by 4.5 feet, sloping in two directions, nichrome heating elements.

14. Conveyor belt, 18 inches wide, 4-ply, 28-ounce duck, rubber surfaced, 1/8-inch top cover, 1/32-inch bottom cover, on 340-foot centers, speed 180 feet per minute, belt-driven by 3-hp. motor.

15. Cross conveyor belt, 18 inches wide, 4-ply, 28-ounce duck, rubber surfaced, 1/8-inch top cover, 1/32-inch bottom cover, on 38-foot centers, speed 180 feet per minute, belt-driven by 3-hp. motor.

16. Stockpile capacity about 5,000 dry tons.

17. Conveyor belt, 18 inches wide, 4-ply, 28-ounce duck, rubber surfaced, 1/8-inch top cover, 1/32-inch bottom cover, on 48-foot centers, speed 180 feet per minute, belt-driven by 3-hp. motor.

18. Bucket elevator, 47 feet long between centers, speed 190 feet per minute, chain-driven by 7-1/2 hp. motor. Buckets, 15 inches long and 7 inches wide, spaced on 18-inch centers.

19. Kiln ore bin, flat bottom, wood-stave construction, capacity 50 tons of wet ore.

20. Challenge feeder, 30 inches in diameter, chain-driven by 3-hp. motor.

21. Conveyor belt, 18 inches wide, 4-ply, 28-ounce duck, rubber surfaced, 1/8-inch top cover, 1/32-inch bottom cover, on 65-foot centers, speed 108 feet per minute, belt-driven by 3-hp. motor.

22. Kiln 60 feet long, 5 feet outside diameter, 3 feet 10 inches inside diameter, slope 1/2-inch per foot, gear-driven by 7-1/2 hp. motor. Lined with 2-1/2 inches of Diatex brick and 4-1/2 inches monolithic fire brick concrete. Equipped with Ryder burner.

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Table 1.—Details of equipment (Continued)

23. Launder, V shape, made of 1-inch boards 12 inches wide. Slope of launder, 6 inches per each 16 feet. Calcine discharges into water flowing in the launder.

24. Steel dust chamber, 12 feet long, 10 feet high, 8 feet wide, equipped with chain curtain. Discharge from dust chamber through V-shaped flue made of steel pipe 30 inches in diameter.

25. Cyclone dust precipitators, 12 in number, grouped in two sets of six each, the groups arranged in parallel.

26. Hot treater, over all dimensions, 25 feet high and 14 by 5 feet in cross section.

27. Spray tower, height 26 feet, 7 by 6 feet in cross section. Water for sprays pumped by 2-3/4 by 4-inch Fairbanks Morse duplex plunger pump, belt-driven by 10-hp. motor.

28. Pipe coil condenser, height 33 feet, 4 by 4-1/2 feet in section, contains 360 Corrosiron pipes, each 5 feet in length and 2-1/2 inches outside diameter.

29. Circular wood-stave tanks, 2 in number, one 30 feet high, 5 feet in diameter, and the other 30 feet high and 16 feet in diameter.

30. Cold treater, 16 feet high, 6 by 10 feet in section.

31. Circular wood-stave tanks, 2 in number, one 30 feet high and 20 feet in diameter, and the other 30 feet high and 16 feet in diameter.

32. Circular wood-stave tanks placed horizontally, each 16 feet long and 8 feet in diameter.

33. Exhaust fan, enclosed in wooden chamber 100 inches in outside diameter. Fan is of Monel metal.

34. Stack, 4 feet in diameter, and 40 feet high, made of wood staves.
35. Wood-stave tanks, 2 in number, each 16 feet in diameter and 5 feet high.
36. Settling tank, 20 feet in diameter and 5 feet high.
37. Concrete sump.
38. Wood launder made of 1-inch boards, 12 by 12 inches in cross section.
39. Wilfley pump, 2-inch centrifugal, direct-connected to 5-hp. motor.
40. Same as item 39.

41. Agitator tank, 10 feet in diameter and 10 feet high. Devereux agitating mechanism driven at 25 r.p.m. by 5-hp. motor. Belt and pinion drive.

42. Two Kraut flotation cells driven by 5-hp. motor with texrope drive.

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Table 1.—Details of equipment (Continued)

43. Launder made of 1-inch boards, cross section of launder 6 by 8 inches.

44. Drum filters made out of 50-gallon oil barrels, canvas filter cloth laid on screen with 1/4-inch holes, which in turn is placed on iron rods. Vacuum 25 inches of mercury maintained by Oliver vacuum pump, belt-driven by 5-hp. motor.

45. Same as 13.

46. Standard D-retorts, 3 in number, with water-jacketed condensing pipe; size of retort fire box 2 by 2 feet in cross section and 9 feet long; retort size 1 by 1-1/2 by 8 feet long. Each retort equipped with Ray oil burner.

47. Iron flasks, each holding 76 pounds 1 ounce of quicksilver.

Table 2 gives metallurgical data sheet and Table 3 the metallurgical balance sheet for the month of April, 1930.

Table 4 gives the wage scale at the plant; table 5 gives a summary of plant costs, and Table 6 presents plant costs in units of labor, power, and supplies.

Table 2.—Metallurgical data for month of April, 1930

Dry ore treated, tons	1,290
Quicksilver produced, pounds	9,118.2
Average quicksilver content per ton of ore, pounds	8.32
Recovery of quicksilver, per cent	84.95
Oil used per dry ton of ore, gallons	22.8
Moisture in ore sent to mill, per cent	30
Temperature of kiln, °C.	625
Temperature in flue discharging from cyclones, °C.	235
Temperature at pipe coil condenser inlet, °C.	70
Temperature at pipe coil condenser outlet, °C.	41
Temperature at stack, °C.	17
Draft at kiln, inches of water	0.18
Draft at pipe coil condenser inlet, inches of water	1.50
Draft at end of condensing systems, inches of water	2.40

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Table 3.—Metallurgical balance sheet for the month of April, 1930

	Weight, dry tons	Assay, pounds quicksilver per ton	Weight of quicksilver, pounds
Screening and sorting plant:			
Low-grade ore mined[1]	9,000	4.50	40,500
Waste rejected	5,400	1.50	8,100
Ore sorted and screened	3,600	9.00	32,400
Ore stored in stock pile	2,310	9.38	21,667
Ore sent to furnace	1,290	8.32	10,733
Furnace plant losses of quicksilver:			
Kiln residues, tonnage estimated to be 95 per cent of feed	1,225.0	0.40	490.0
Cyclone dust, tonnage estimated	45.0	2.50	113.0
Flotation tailings	40.0	2.00	80.0
Low-grade mud	2.1	21.43	45.0
Retort residues, tonnage estimated	18.0	0.40	7.0
Stack losses, estimated	-	-	300.0
Unaccounted for	-	-	579.8
Total loss of mercury	-	-	1,614.8
Furnace plant production of mercury:			
From condenser	-	-	5,107.2
From retorting of mud	-	-	1,731.0
From retorting of table concentrates	-	-	91.2
From retorting flotation concentrates	-	-	1,094.4
From monthly clean-up	-	-	1,094.4
Total production for month	-	-	9,118.2
Distribution of monthly clean-up mercury:			
Horizontal tanks	-	-	87.5
Tanks 3 and 4	-	-	54.7
Cold treater	-	-	207.9
Tanks 1 and 2	-	-	404.9
Spray tower and condenser	-	-	186.1
Agitator	-	-	153.3
Total	-	-	1,094.4

1 - Wet weight of ore, 12,857 tons. Assay content of wet ore 3.15 pounds quicksilver per ton.

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Table 4.—Wage scale

	Per 8-hour shift
Screening and sorting operations:	
Grizzly man, skip loader, and plant helpers	$4.50
Hoistman and plant operator	5.50
Furnace, flotation, retort, condenser, and miscellaneous operations:	
Plant operators	5.50
Plant helpers and general labor	4.50
Retort and drag-line operator	5.00
Carpenter	6.00
Blacksmith and electrician	6.50
Assaying:	
Assayer	5.00

Table 5.—Summary of costs per ton of ore treated for April, 1930

Tons of dry ore treated: 1,290. Pounds of quicksilver produced: 9,118.2.

	Labor	Power	Oil	Reagents	Other supplies	Total
Screening and sorting[1]	$0.594	$0.135	—	—	$0.106	$0.835
Furnace treatment	.138	.018	$1.368	—	.185	1.709
Flotation	.246	.029	—	$0.044	.068	.387
Retorting	.031	.016	.073	.029	.028	.177
Assaying	.078	.008	—	—	.021	.107
Condensing	.315	.034	—	—	.185	.534
Miscellaneous	.116	[2].174	—	—	.069	.359
Total	$1.518	$0.414	$1.441	$0.073	$0.662	$4.108

1 - Includes crushing of the ore sorted on picking belt.

2 - Includes water pumping, exhausting furnace gases, and conveying.

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Table 6.—Summary of costs in units of labor, power, and supplies for April, 1930

Tons of dry ore treated: 1,290. Pounds of quicksilver produced: 9,118.2.

Labor, man-hours per ton:	
Screening and sorting	0.950
Furnace treatment	.210
Flotation	.373
Retorting	.047
Condensing	.477
Assaying	.125
Miscellaneous	.176
Total	2.358
Tons per man per 8-hour shift	3.393
Power, kw. h. per ton:	
Screening and sorting	10.80
Furnace treatment	1.44
Flotation	2.32
Retorting	1.28
Assaying	0.64
Condensing	2.72
Miscellaneous	13.92
Total	33.12
Supplies:	
Oil consumption, gallons per ton of dry ore:	
Furnace treatment	22.8
Retorting	1.2
Total	24.0
Reagents, pounds per ton of ore:	
Sodium aerofloat	0.0543
Pine oil	0.3093
Barrett No. 4	0.0186
Lime	1.954
Labor, percentage of total cost	36.9
Power and supplies, percentage of total cost	63.1

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